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(74) Agents: DIEHL, Robert, A. et al.; Columbia IP Law Group, LLC, 4900 SW Meadows Road, Suite 109, Lake Oswego, OR 97035 (US).

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(71) Applicant: MOBILIAN CORPORATION [US/US];
7431 NW Evergreen Parkway, Suite 220, Hillsboro, OR
97124 (US).

(71) Applicants and

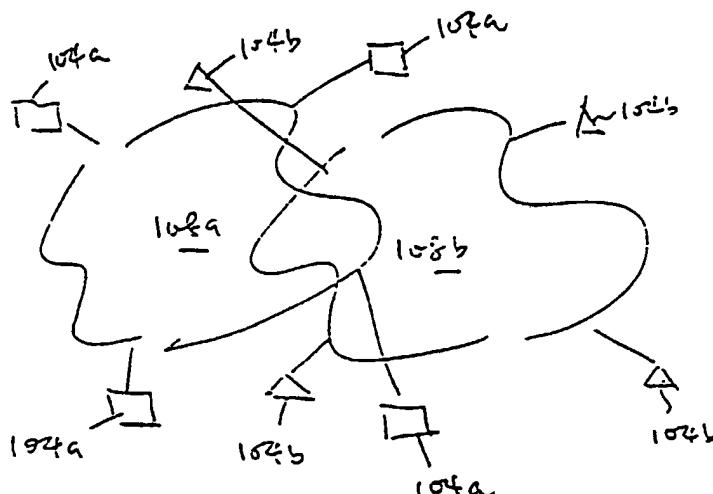
(72) Inventors: NEVO, Ron [IL/US]; 2767 NW Overlook Drive #2311, Hillsboro, OR 97124 (US). MONELLO, Brett, A. [US/US]; 18117 Westminster Drive, Lake Oswego, OR 94037 (US).

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(57) Abstract: A wireless device is provided with a wireless transceiver to transmit and receive signals in accordance with a first protocol to and from network devices of a first wireless network, and a controller manager to control operation of the wireless transceiver. The wireless device is further provided with a wireless receiver to receive signals transmitted in accordance with a second protocol by network devices of a second wireless network, and the controller manager is equipped to control operation of the wireless transceiver based at least in part on at least one signaling characteristic of the received signals from network devices of the second wireless network, to reduce interference with proximately located ones of the network devices of the second wireless network. In various

embodiments, the controller manager suspends operation of the wireless transceiver whenever interference is predicted. In other embodiments, the controller manager causes an appropriate filter to be applied whenever interference is predicted.

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**WIRELESS COMMUNICATION OF CONCURRENT VOICE AND DATA
USING OVERLAPPING PROTOCOLS**

The present U.S. Patent application is a continuation-in-part of U.S. Patent application number 09/439,946, filed November 12, 1999 entitled "MULTIPLE WIRELESS COMMUNICATION PROTOCOL METHODS AND APPARATUSES," which is a continuation-in-part of U.S. Patent application number 09/408,725, filed September 29, 1999, entitled "A WIRELESS APPARATUS HAVING MULTIPLE COORDINATED TRANSCEIVERS FOR MULTIPLE WIRELESS COMMUNICATION PROTOCOLS". The present U.S. Patent application is also a continuation-in-part of U.S. Patent application number 09/438,215, filed November 12, 1999, entitled "WIRELESS APPARATUS INTERFERENCE AVOIDANCE/RESOLUTION METHODS AND APPARATUSES."

FIELD OF THE INVENTION

The present invention relates to the field of wireless communication. More specifically, the present invention relates to the problem of concurrent wireless voice and data communication with multiple communication partners of different wireless communication protocols.

BACKGROUND OF THE INVENTION

Advances in microprocessor and communication technology have led to the increase in popularity of wireless communication. Once confined to the privileged, wireless voice communication have become affordable and available to the masses. Today, various efforts are under way to apply wireless communication to replace attachment cables used for attaching peripheral devices, such as printers, scanners and the like, as well as networking cables used for connecting clients, servers and the like. Examples of technology to accomplish these goals include the different variants of the IEEE 802.11 Standard published by the Institute of Electrical and Electronic Engineers,

802.11 (Frequency Hopping, Direct Sequence), 802.11a, 802.11b, as well as Home RF, also known as Shared Wireless Access Protocol (SWAP) to those skilled in the art.

It is desirable for various applications (e.g., voice and data) to have wireless devices that operate in accordance with different protocols, and overlapping frequencies, to operate proximately located to each other. Most wireless protocols employ carrier sense collision detection, and random back off to resolve collision or interference. However, experience has shown that prior art collision detection and back off approaches could substantially degrade the performance of both networks operating with overlapping frequencies. Accordingly, an improved approach to allow wireless devices operating with different protocols and overlapping frequencies to operate proximately close to each other is needed.

SUMMARY OF THE INVENTION

A first block of data is transmitted according to a first protocol. A second block of data is transmitted in one of multiple slots in a first packet and one of multiple slots in a second packet according to a second protocol when no conflict exists between transmission of the first block of data and transmission of the first and second packets of the second protocol. In one embodiment, the first packet and the second packet are transmitted at different frequencies. Transmission of one of the first packet and the second packet is blocked when the other of the first packet and the second packet transmitted according to the second protocol conflicts with transmission of the first block of data. Transmission of the first packet and the second packet is blocked when the first packet and the second packet transmitted according to the second protocol conflict with transmission of the first block of data.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings in which like reference numerals refer to similar elements.

Figure 1 illustrates one embodiment of an overlapping network environment incorporated with the teachings of the invention.

Figures 2a-2b illustrate one embodiment of an architectural view and operation flow of “fully” enhanced wireless devices.

Figure 3 is a flow chart of one embodiment support for simultaneous operation of IEEE 802.11 and SWAP.

Figures 4a-4b illustrate one embodiment of an architectural view and operation flow of “fully” enhanced wireless devices in further detail.

Figures 5a-5b illustrate one embodiment of an architectural view and operation flow of “fully” enhanced wireless devices in further detail.

Figures 6a-6b illustrate one embodiment of an architectural view and operation flow of “fully” enhanced wireless devices in further detail.

Figure 7 illustrates the concept of a notch filter.

DETAILED DESCRIPTION

In the following description, various aspects of the present invention will be described. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some or all aspects of the present invention. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the present invention. However, it will also be apparent to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well known features are omitted or simplified in order not to obscure the present invention.

Parts of the description will be presented using software terminology commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. As well understood by those skilled in the art, these software quantities take the

form of electrical, magnetic, or optical signals capable of being stored, transferred, combined, and otherwise manipulated through mechanical and electrical components of a digital system; and the term digital system includes general purpose as well as special purpose processors, systems, and the like, that are standalone, adjunct or embedded.

Various operations will be described as multiple discrete steps performed in turn in a manner that is most helpful in understanding the present invention, however, the order of description should not be construed as to imply that these operations are necessarily order dependent, in particular, the order the steps are presented. Furthermore, the phrase "in one embodiment" will be used repeatedly, however the phrase does not necessarily refer to the same embodiment, although it may.

Referring now to **Figure 1**, wherein an overview of an overlapping network environment incorporated with the teachings of the present invention is shown. As illustrated, overlapping wireless network environment 100 includes wireless network devices 104a of first wireless network 108a operating in accordance with a first wireless protocol (e.g., SWAP), and wireless network devices 104b of second wireless network 108b operating in accordance with a second wireless protocol (e.g., IEEE 802.11). Wireless devices 104a and 104b are proximately located to each other, with at least some of wireless devices 104a and 104b being sufficiently close, such that when they transmit on the same frequency, they interfere (or "collide" or "conflict") with each other. One or more wireless devices 104a and 104b are incorporated with the teachings of the present invention to facilitate proactive interference avoidance or resolution. As a result, the number of conflicts and the number of times wireless devices 104a and 104b go through the costly prior art back off, retry approaches are reduced, leading to overall improvement in efficiency for both wireless networks 108a-108b.

In one embodiment, all devices 104a are incorporated with the teachings of the present invention to predict when an interference will occur, and proactively avoid or resolve the interference (hereinafter, "fully enhanced" devices). In another embodiment, only some of devices 104a are so enhanced (one or more). In yet another embodiment, while only some of devices 104a are so enhanced (one or more), other devices 104a not so "enhanced" are nevertheless "minimally enhanced" to request the "fully enhanced" devices

104a to at least preemptively notify them on when an interference is predicted to occur (hereinafter, “minimally enhanced” devices). The “fully enhanced” devices **104a** are further equipped to provide the preemptive notifications.

Likewise, in one embodiment, all devices **104b** are incorporated with the teachings of the present invention to predict when an interference will occur, and proactively avoid or resolve interference (hereinafter, “fully enhanced” devices). In another embodiment, only some of devices **104b** are so enhanced. In yet another embodiment, while only some of devices **104b** are so enhanced, other devices **104b** not so enhanced are nevertheless “minimally” enhanced to request the “fully enhanced” devices **104b** to at least preemptively notify them on when interference is predicted to occur (hereinafter, “minimally enhanced” devices). The “fully enhanced” devices **104b** are further equipped to provide the preemptive notifications.

In one embodiment, wireless network protocol **108a** is IEEE 802.11b and wireless network protocol **108b** is SWAP 1.1. Other protocols can also be used, for example, IEEE 802.11a, other IEEE 802.11 protocols, other versions of SWAP, etc. In one embodiment, wireless network protocol **108a** uses a 22 MHz range around a center frequency to transmit and receive data. In an alternate embodiment, wireless network protocol **108a** uses a 16 MHz range around a center frequency to transmit and receive data. Other ranges can also be used. In one embodiment, wireless network protocol **108b** transmits and receives both voice and data information on a sequence of frequencies in 20 ms intervals. Furthermore, SWAP packets have two 2.4 ms voice fields and voice information is transmitted in voice fields of two consecutive packets. Thus, voice data is transmitted at two different frequencies.

Figures 2a-2b illustrate the architecture and operational flow of an enhanced wireless device **104b** of Fig. 1 in accordance with one embodiment (a “fully enhanced” embodiment). Wireless devices **104b** are enhanced to be voluntary dominated devices, allowing wireless devices **104a** to be the dominant devices, to proactively avoid interference. Enhanced wireless devices **104b** are to predict when an interference will occur, and at each of such predicted occurrence, voluntarily suspend operation (for a brief moment) to proactively refrain from interfering with wireless devices **104a**.

As illustrated in Fig. 2a, to enable wireless devices 104b to so operate, each wireless device 104b, in addition to conventional transceiver 1008 and controller manager 1006, is additionally provided with state machine 1004, receiver 1007 and interference avoidance manager 1005. The elements are coupled to each other as shown.

Receiver 1007 is used to additionally receive signals transmitted in accordance with the first protocol (e.g., IEEE 802.11) between wireless devices 104a, thus allowing the enhanced wireless device 104b, to be able to receive signals in the first protocol, in addition to transmitting and receiving signals in the second protocol (e.g., SWAP). Interference avoidance manager 1005 is equipped to determine at least a signaling characteristic of the first protocol, and predicts when an interference will occur, based on the determined one or more signal characteristics. For the illustrated embodiment, interference avoidance manager 1005 determines the frequency used by devices 104a, and predicts when an interference will occur based on the determined frequency or frequency hopping pattern. The determination may be made in any one of a number of techniques known in the art.

State machine 1004 is used to periodically generate a TX/RX or NOP control signal for controller manager 1006 to control transceiver 1008 accordingly, i.e. to transmit/receive or suspend operation (to proactively avoid interference). State machine 1004 generates the TX/RX or NOP control signal based on whether an interference is predicted by interference avoidance manager 1005.

As illustrated in Fig. 2b, state machine 1004, in addition to idle state 1010, has two operating states (S1-S2) 1012-1014. In state S1, state machine 1004 outputs the TX/RX control signal denoting performance of transmit/receive operation, and in state S2, state machine 1004 outputs the NOP control signal denoting suspension of transmit/receive operation.

Upon power-on or reset, state machine 1004 transitions from idle state 1010 to S1 state 1012. While in S1 state 1012, state machine 1004 remains in the state as long as an interference is not predicted by interference avoidance manager 1005, outputting the TX/RX control signal for controller manager 1006. Whenever an interference is predicted by interference avoidance manager 1005, state machine 1004 transitions from S1 state

1012 to S2 state **1014**. While in S2 state **1014**, state machine **1004** remains in the state for a predetermined duration, outputting the NOP signal denoting suspension of transmit/receive operations for controller manager **1006**. The predetermined duration may be “hardwired”, denoted through jumpers, or set through configuration registers, and the like. Upon expiration of the predetermined duration, state machine **1004** transitions from S2 state **1014** to S1 state **1012**. From S1 state **1012**, state machine **1004** continues operation as described earlier.

Except for the generation of the TX/RX and NOP control signals, and the control of transceiver **1008** by controller manager **1006** in accordance with these control signals, proactively avoiding interference with wireless device **104a**, each wireless device **104b**, including controller manager **1006** and transceiver **1008**, otherwise operates as known in the art.

Referring again to Fig. 2a, in one embodiment, in support of the “minimally enhanced” devices **104b**, interference avoidance manager **1005** further monitors signals received by transceiver **1008** from other devices **104b**. In particular, interference avoidance manager **1005** monitors for requests from other “minimally enhanced” devices **104b** to be preemptively notified of a predicted occurrence of an interference. Upon receiving at least one such request, interference avoidance manager **1005** further causes each prediction to be broadcast for other devices **104b**, thereby allowing the “minimally enhanced” devices **104b** to be able to voluntarily behave as dominated devices (in favor of wireless devices **104a**, the dominant devices).

A “minimally enhanced” device **104b** may be constituted by slightly modifying controller manager **1006**, and additionally provided with only state machine **1007** (i.e., without providing receiver **1007** and interference manager **1005**). Controller manager **1006** is slightly modified to broadcast a request to the “fully enhanced” devices **104b**, to preemptively provide a prediction of interference, as described earlier. The broadcast e.g. may be made upon power on, reset, or periodically. State machine **1007** operates substantially as described earlier, i.e. outputting TX as long as no prediction of an interference occurrence is received, and outputting NOP for a predetermined duration whenever a prediction of an interference occurrence is received.

In one embodiment, in order to avoid conflicts between IEEE 802.11 transactions (transmit or receive) and SWAP transactions, if the SWAP-based transaction falls within the IEEE 802.11 transaction frequency the SWAP packet is not transmitted. As mentioned above, blocks of voice data are transmitted in slots of two consecutive SWAP packets. For a particular block of voice data, if one of the two packets in which the block is transmitted is blocked, the block of data is still transmitted. However, the advantages (e.g., error correction) available from transmitting the block of data twice are reduced.

If both packets in which the block of data is to be transmitted are blocked, the block of data is lost and not transmitted in subsequent packets. As described below, the probability of not transmitting a block of data is relatively low and the block of data represents only 2.4 ms of voice data, which is a relatively small loss.

Because the hop sequence of SWAP is a simple cycle between frequencies in a pseudo-random manner, the number of collisions can be quite low. Table 1 shows the collision probability for each possible IEEE 802.11 band assuming 22 MHz filters are used.

| Center Frequency (MHz) | 2412 | 2417 | 2422 | 2427 | 2432 | 2437 | 2442 |
|------------------------|-------|-------|-------|------|-------|-------|-------|
| Number of Hits | 1 | 4 | 2 | 0 | 2 | 4 | 3 |
| Probability | 0.002 | 0.007 | 0.003 | 0 | 0.003 | 0.007 | 0.005 |
| Center Frequency (MHz) | 2447 | 2452 | 2457 | 2462 | 2467 | 2472 | |
| Number of Hits | 5 | 1 | 1 | 0 | 2 | 2 | |
| Probability | 0.008 | 0.002 | 0.002 | 0 | 0.003 | 0.003 | |

Table 1: Hit probability for IEEE 802.11B with 22 MHz bands and SWAP 1.1

The center frequencies are the possible center frequencies while operating according to IEEE 802.11. The number of hits is the number of consecutive hop pairs that fall within the 22 MHz band of the IEEE 802.11 center frequency. The probability is the probability of a hit assuming a 309 μ sec IEEE 802.11 slot with four simultaneous SWAP supported calls.

If 16 MHz band are used with IEEE 802.11 communications, the number of hits is further reduced.

| Center Frequency (MHz) | 2412 | 2417 | 2422 | 2427 | 2432 | 2437 | 2442 |
|------------------------|------|-------|------|------|-------|-------|-------|
| Number of Hits | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| Probability | 0 | 0.002 | 0 | 0 | 0.002 | 0.002 | 0.002 |
| Center Frequency (MHz) | 2447 | 2452 | 2457 | 2462 | 2467 | 2472 | |
| Number of Hits | 0 | 1 | 0 | 0 | 0 | 1 | |
| Probability | 0 | 0.002 | 0 | 0 | 0 | 0.002 | |

Table 2: Hit probability for IEEE 802.11B with 16 MHz bands and SWAP 1.1

The number of hits is the number of consecutive hop pairs that fall within the 16 MHz band of the IEEE 802.11 center frequency. The probability is the probability of a hit assuming a 309 μ sec IEEE 802.11 slot with four simultaneous SWAP supported calls. Thus, by using narrower band filters for IEEE 802.11 communications, the amount of SWAP data lost can be reduced.

Figure 3 is a flow chart of one embodiment support for simultaneous operation of IEEE 802.11 and SWAP. Packets are generated according to IEEE 802.11 and/or SWAP at 310. Generation of data and/or voice packets according to IEEE 802.11 and SWAP are known to those of ordinary skill in the art.

Controller managers 106a and/or 106b determine whether a collision will occur between an IEEE 802.11 packet and one or more SWAP packets at 320. A collision occurs if both transceiver 102a and transceiver 102b attempt to transmit or receive packets at the same frequency at the same time. If no collision is detected at 320 the IEEE 802.11 packet and/or the SWAP 1.1 packet are transmitted at 330. The process then repeats for subsequent transmissions.

If a collision is detected at 320, the IEEE 802.11 packet is transmitted at 340. The SWAP packets that cause the collision are aborted at 350. Any number of SWAP packets can be aborted to avoid a collision. Typically, however, only one or two SWAP packets are aborted. The process then repeats for subsequent transmissions. In one embodiment, aborting the SWAP packet(s) causes 2.4 μ sec of voice data to be lost per packet.

Figures 4a-4b illustrate the architecture and operational flow of an enhanced wireless device 104a of Fig. 1 in accordance with one embodiment (a “fully enhanced”

embodiment). As described earlier, wireless devices 104a are enhanced to be the voluntary dominated devices, allowing wireless devices 104b to be the dominant devices, to proactively avoid interference. In one embodiment, the dominated device is a SWAP device and the dominate device is an IEEE 802.11 direct sequence spread spectrum (DSSS) device. Other configurations can also be provided. Enhanced wireless devices 104a are to determine when a current frequency interferes with wireless device 104b, and at each of such determination (or “prediction”, albeit with certainty), voluntarily suspend operation (for a brief moment) to proactively refrain from interfering with wireless devices 104b.

As illustrated in Fig. 4a, to enable wireless devices 104a to so operate, each wireless device 104a, in addition to conventional transceiver 1108 and controller manager 1106, is additionally provided with receiver 1107 and interference avoidance manager 1105. The elements are coupled to each other as shown.

Receiver 1107 is used to additionally receive signals transmitted in accordance with the second protocol between wireless devices 104b, thus allowing the enhanced wireless device 104a, to be able to receive signals in the second protocol, in addition to transmitting and receiving signals in the first protocol. Interference avoidance manager 1105 is equipped to determine at least a signaling characteristic of the second protocol, monitor controller manager 1106, determine if an interference is to occur based on the determined one or more signal characteristics, and proactively avoid the interference. For the illustrated embodiment, interference avoidance manager 1105 determines the signaling frequency of the second protocol, monitors the pseudo random frequency hopping pattern of controller manager 1106, and determines if a current frequency is the same as the signaling frequency of the second protocol.

As illustrated in Fig. 4b, interference avoidance manager 1105 checks for interference, as controller manager 1106 controls transceiver 1108, hopping from frequency to frequency, 1112. If the current frequency is not the interfering frequency, interference avoidance manager 1105 allows controller manager 1106 to operate transceiver 1108 as known in the art, 1114; otherwise, it causes controller manager 1106 to suspend transmit/receive operation, 1116, pro-actively avoiding interference.

Except for the inclusion of receiver 1107 and interference avoidance manager 1105, each wireless device 104a, including controller manager 1106 and transceiver 1108, otherwise operates as known in the art.

Referring again to Fig. 4a, in one embodiment, in support of the “minimally enhanced” devices 104a, interference avoidance manager 1105 further monitors signals received by transceiver 1108 from other devices 104a. In particular, interference avoidance manager 1105 monitors for requests from other “minimally enhanced” devices 104a to be preemptively notified of a “predicted” occurrence of an interference. Upon receiving at least one such request, interference avoidance manager 1105 further causes each prediction to be broadcast for other devices 104a, thereby allowing the “minimally enhanced” devices 104a to be able to voluntarily behave as dominated devices (in favor of wireless devices 104b, the dominant devices).

A “minimally enhanced” device 104a may be constituted by slightly modifying controller manager 1106 (i.e., without providing receiver 1107 and interference manager 1105). Controller manager 1106 is slightly modified to broadcast a request to “fully enhanced” devices 104a, to preemptively provide a prediction of interference, as described earlier. The broadcast may be made e.g. at power on, reset or periodically. Otherwise, controller manager 1107 operates substantially as described earlier, i.e. operating transceiver 1108 to transmit and receive signals as long as no prediction of an interference occurrence is received, and suspending operation of transceiver 1108 for a predetermined duration whenever a prediction of an interference occurrence is received.

Figures 5a-5b illustrate the architecture and operational flow of an enhanced wireless device 104b of Fig. 1 in accordance with another embodiment (another “fully enhanced” embodiment). As described earlier, wireless devices 104b are enhanced to proactively resolve interference. Enhanced wireless devices 104b are to predict when an interference will occur, and at each of such predicted occurrence, apply an appropriate filter (for a brief moment) to remove interfering signals of wireless devices 104a. In one embodiment, wireless devices 104a are SWAP devices and wireless devices 104b are IEEE 802.11 frequency hopping spread spectrum (FHSS) devices.

As illustrated in Fig. 5a, to enable wireless devices 104b to so operate, each wireless device 104b, in addition to conventional transceiver 1208 and controller manager 1206, is additionally provided with receiver 1207 and interference resolution manager 1205. The elements are coupled to each other as shown.

Receiver 1207 is used to additionally receive signals transmitted in accordance with the first protocol between wireless devices 104a, thus allowing the enhanced wireless devices 104b, to be able to receive signals in the first protocol, in addition to transmitting and receiving signals in the second protocol. Interference resolution manager 1205 is equipped to determine at least a signaling characteristic of the first protocol, and predicts when an interference will occur, based on the determined one or more signal characteristics.

For the illustrated embodiment, interference resolution manager 1205 determines the frequency hopping pattern followed by devices 104a, and predicts when an interference will occur based on the determined frequency hopping pattern. The determination may be made in any one of a number of techniques known in the art. Additionally, interference resolution manager 1205 further determines an appropriate filter to be applied to remove the interfering signals of wireless devices 104a at each predicted occurrence of interference. In one embodiment, the appropriate filter is a notch filter, inversely formed based on the interfering signal (as illustrated in Fig. 7).

Thus, as illustrated in Fig. 5b, upon power on or reset, interference resolution manager 1205 monitors the transmit signals of devices 104a to determine the pseudo random frequency hopping pattern followed by devices 104a, and the appropriate filter to apply, 1210. Thereafter, interference resolution manager 1205 determines if an interference is to occur, based on the determined pseudo random frequency hopping pattern, 1212. Whenever an interference is predicted to occur, interference resolution manager 1205 outputs the appropriate control signal and filtering information for controller manager 1206 to apply the appropriate filter to proactively remove the interfering signals of wireless devices 104a, 1214.

Except for the determination of the pseudo random frequency hopping pattern of wireless devices 104a, the determination of the appropriate filter, predicting when an

interference will occur, and causing controller manager 1206 to apply the determined appropriate filter, each enhanced wireless device 104b, including controller manager 1206 and transceiver 1208, otherwise operates as known in the art.

Referring again to Fig. 5a, in one embodiment, in support of the “minimally enhanced” devices 104b, interference resolution manager 1205 further monitors signals received by transceiver 1208 from other devices 104b. In particular, interference resolution manager 1005 monitors for requests from other “minimally enhanced” devices 104b to be preemptively notified of a predicted occurrence of an interference. Upon receiving at least one such request, interference resolution manager 1205 further causes each prediction to be broadcast for other devices 104b, including the appropriate filter to apply, thereby allowing the “minimally enhanced” devices 104b to be able to also proactively resolve interference.

A “minimally enhanced” device 104b likewise may also be constituted by merely slightly modifying controller manager 1206. Controller manager 1206 is slightly modified to broadcast a request to “fully enhanced” devices 104b, to preemptively provide a prediction of interference, as described earlier. Again, the broadcast may be made e.g. at power on, reset, or periodically. Controller manager 1206 further causes the appropriate filter to be applied to received signals, whenever a prediction of an interference occurrence is received.

Figures 6a-6b illustrate the architecture and operational flow of an enhanced wireless device 104a of Fig. 1, in accordance with another embodiment (another “fully enhanced” embodiment). As described earlier, wireless devices 104a are enhanced to proactively resolve interference. Enhanced wireless devices 104a are to predict when an interference will occur, and at each of such predicted occurrence, apply an appropriate filter (for a brief moment) to remove interfering signals of wireless devices 104b.

As illustrated in Fig. 6a, to enable wireless devices 104a to so operate, each wireless device 104a, in addition to conventional transceiver 1308 and controller manager 1306, is additionally provided with receiver 1307 and interference resolution manager 1305. The elements are coupled to each other as shown.

Receiver 1307 is used to additionally receive signals transmitted in accordance with the second protocol between wireless devices 104b, thus allowing the enhanced wireless device 104a, to be able to receive signals in the second protocol, in addition to transmitting and receiving signals in the first protocol. Interference resolution manager 1305 is equipped to determine at least a signaling characteristic of the second protocol, determine if an interference is to occur based on the determined one or more signal characteristics, and proactively avoid the interference. For the illustrated embodiment, interference avoidance manager 1105 determines the signaling frequency of the second protocol. Additionally, interference resolution manager 1305 further determines an appropriate filter to be applied to remove the interfering signals of wireless devices 104b at each predicted occurrence of interference. In one embodiment, the appropriate filter is also a notch filter, inversely formed based on the interfering signal (as illustrated in Fig. 7).

Thus, as illustrated in Fig. 6b, upon power on or reset, interference resolution manager 1305 monitors the transmit signals of devices 104b to determine the signaling frequency of devices 104b, and the appropriate filter to apply, 1310. Thereafter, interference resolution manager 1305 monitors the pseudo random frequency hopping pattern of controller manager 1306, and determines if the current frequency is the same as the signaling frequency of devices 104b, 1312. If the current frequency is not the interfering frequency, interference resolution manager 1305 allows controller manager 1306 to operate transceiver 1308 as known in the art, otherwise, interference resolution manager 1305 outputs the appropriate control signal, including the filtering information, to cause controller manager 1306 to apply the appropriate filter to the received signals, to proactively resolve interference, 1314.

Except for the inclusion of receiver 1307 and interference resolution manager 1305, each wireless device 104a, including controller manager 1106 and transceiver 1108, otherwise operates as known in the art.

Referring again to Fig. 6a, in one embodiment, in support of “minimally enhanced” devices 104a, interference resolution manager 1305 further monitors signals received by transceiver 1308 from other devices 104a. In particular, interference resolution manager 1305 monitors for requests from other “minimally enhanced” devices 104a to be

preemptively notified of a “predicted” occurrence of an interference. Upon receiving at least one such request, interference resolution manager 1305 further causes each prediction to be broadcast for other devices 104a, thereby allowing the “minimally enhanced” devices 104a to also proactively resolve interference.

A “minimally enhanced” device 104a may likewise be constituted by merely slightly modifying controller manager 1306 (i.e., without providing receiver 1307 and interference manager 1305). Controller manager 1306 is slightly modified to broadcast a request to “fully enhanced” device 104a, to preemptively provide a prediction of interference and associated filtering information, as described earlier. Otherwise, controller manager 1307 operates substantially as described earlier, i.e. operating transceiver 1308 to transmit and receive signals as long as no prediction of an interference occurrence is received, and proactively filters received signals whenever a prediction of an interference occurrence is received.

Thus, wireless devices equipped to proactively avoid interference have been described. While the present invention has been described in terms of the above illustrated embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described. The present invention can be practiced with modification and alteration within the spirit and scope of the appended claims. For example, in each of the “filtering” embodiments, the appropriate filtering may be “recursively” or “incrementally” determined. As a further example, each of enhanced wireless devices 104a and 104b may be further enhanced to allow the pro-active interference avoidance/resolution function to be configurally enabled or disabled. The description is thus to be regarded as illustrative instead of restrictive on the present invention.

CLAIMS

What is claimed is:

1. A method comprising:

transmitting a first block of data according to a first protocol;

transmitting a second block of data in one of multiple slots in a first packet and one of multiple slots in a second packet according to a second protocol when no conflict exists between transmission of the first block of data and transmission of the first and second packets of the second protocol, wherein the first packet and the second packet are transmitted at different frequencies;

blocking transmission of one of the first packet and the second packet when the other of the first packet and the second packet transmitted according to the second protocol conflicts with transmission of the first block of data; and

blocking transmission of the first packet and the second packet when the first packet and the second packet transmitted according to the second protocol conflict with transmission of the first block of data.

2. The method of claim 1 wherein the first protocol comprises IEEE 802.11 protocols.

3. The method of claim 1 wherein the second protocol comprises Shared Wireless Access Protocol (SWAP).

4. The method of claim 1 wherein the second protocol communicates voice data.

5. The method of claim 1 wherein data transmitted according to the second protocol is voice data.

6. The method of claim 1 wherein packets communicated according to the first protocol are for use with a first network and packets communicated according to the second protocol are for use with a second network.

7. The method of claim 1 further comprising adaptively managing time sharing between packets communicated according to the first protocol and packets communicated according to the second protocol.

8. The method of claim 7 wherein adaptively managing time sharing is based, at least in part, on transmit or receive workloads of a first wireless transceiver and a second wireless transceiver that communicate according to the first protocol and the second protocol, respectively.

9. A machine-readable medium having stored thereon sequences of instructions that, when executed, cause one or more electronic systems to:

transmit a first block of data according to a first protocol;

transmit a second block of data in one of multiple slots in a first packet and one of multiple slots in a second packet according to a second protocol when no conflict exists between transmission of the first block of data and transmission of the first and second packets of the second protocol, wherein the first packet and the second packet are transmitted at different frequencies;

block transmission of one of the first packet and the second packet when the other of the first packet and the second packet transmitted according to the second protocol conflicts with transmission of the first block of data; and

block transmission of the first packet and the second packet when the first packet and the second packet transmitted according to the second protocol conflict with transmission of the first block of data.

10. The machine-readable medium of claim 9 wherein the first protocol comprises IEEE 802.11 protocols.

11. The machine-readable medium of claim 9 wherein the second protocol comprises Shared Wireless Access Protocol (SWAP).

12. The machine-readable medium of claim 9 wherein data transmitted according to the second protocol is voice data.

13. The machine-readable medium of claim 9 wherein packets communicated according to the first protocol are for use with a first network and packets communicated according to the second protocol are for use with a second network.

14. The machine-readable medium of claim 9 further comprising sequences of instructions that, when executed, cause the one or more electronic systems to adaptively manage time sharing between packets communicated according to the first protocol and packets communicated according to the second protocol.

15. The machine-readable medium of claim 14 wherein adaptively managing time sharing is based, at least in part, on transmit or receive workloads of a first wireless transceiver and a second wireless transceiver that communicate according to the first protocol and the second protocol, respectively.

16. An apparatus comprising:

a first wireless transceiver to transmit a first block of data according to a first protocol; and

a second wireless transceiver to transmit a second block of data in one of multiple slots in a first packet and one of multiple slots in a second packet according to a second protocol when no conflict exists between transmission of the first block of data and transmission of the first and second packets of the second protocol, wherein the first packet and the second packet are transmitted at different frequencies, to block transmission of one of the first packet and the second packet when the other of the first packet and the second

packet transmitted according to the second protocol conflicts with transmission of the first block of data, and to block transmission of the first packet and the second packet when the first packet and the second packet transmitted according to the second protocol conflict with transmission of the first block of data.

17. The apparatus of claim 16 wherein the first protocol comprises IEEE 802.11 protocols.

18. The apparatus of claim 16 wherein the second protocol comprises Shared Wireless Access Protocol (SWAP).

19. The apparatus of claim 16 wherein data transmitted according to the second protocol is voice data.

20. The apparatus of claim 16 wherein packets communicated according to the first protocol are for use with a first network and packets communicated according to the second protocol are for use with a second network.

21. The apparatus of claim 16 further comprising a control circuit coupled to the first wireless transceiver and to the second wireless transceiver, the control circuit to adaptively manage time sharing between packets communicated according to the first protocol and packets communicated according to the second protocol.

22. The apparatus of claim 21 wherein adaptively managing time sharing is based, at least in part, on transmit or receive workloads of the first wireless transceiver and the second wireless transceiver.

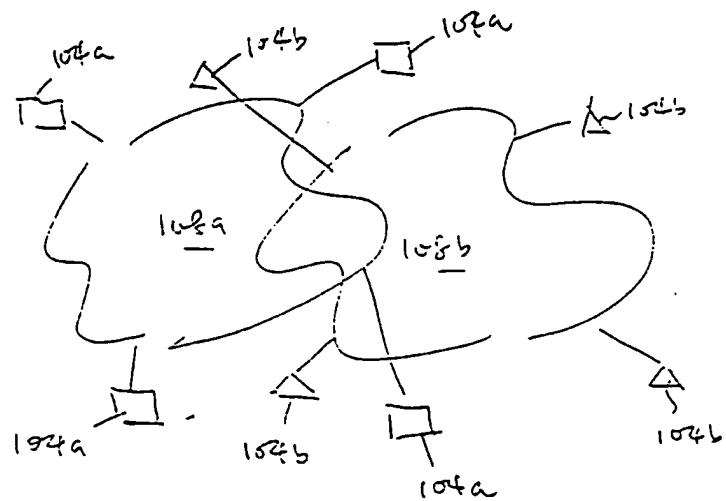


FIG. 1

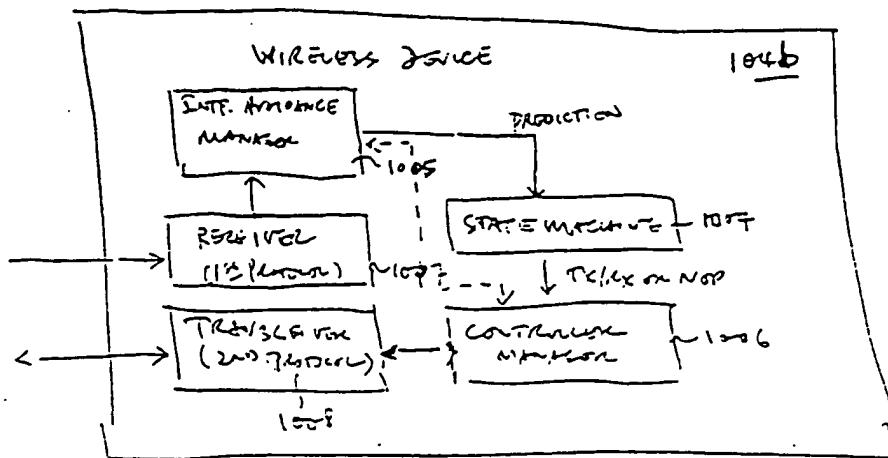


FIG. 2a

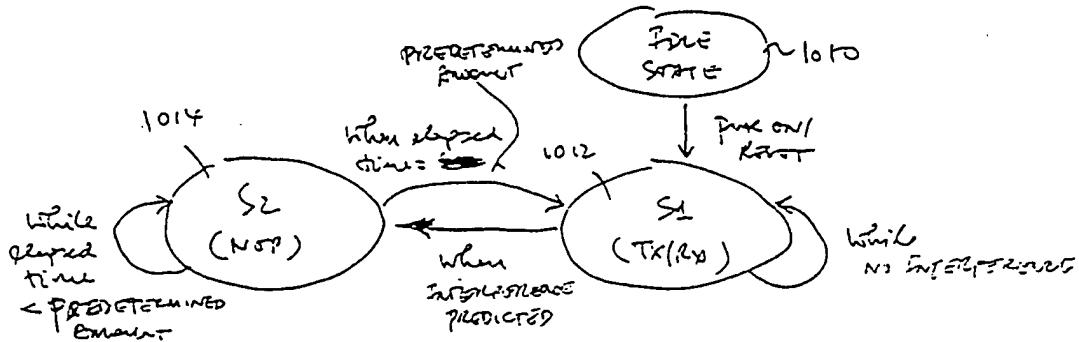


FIG. 2b

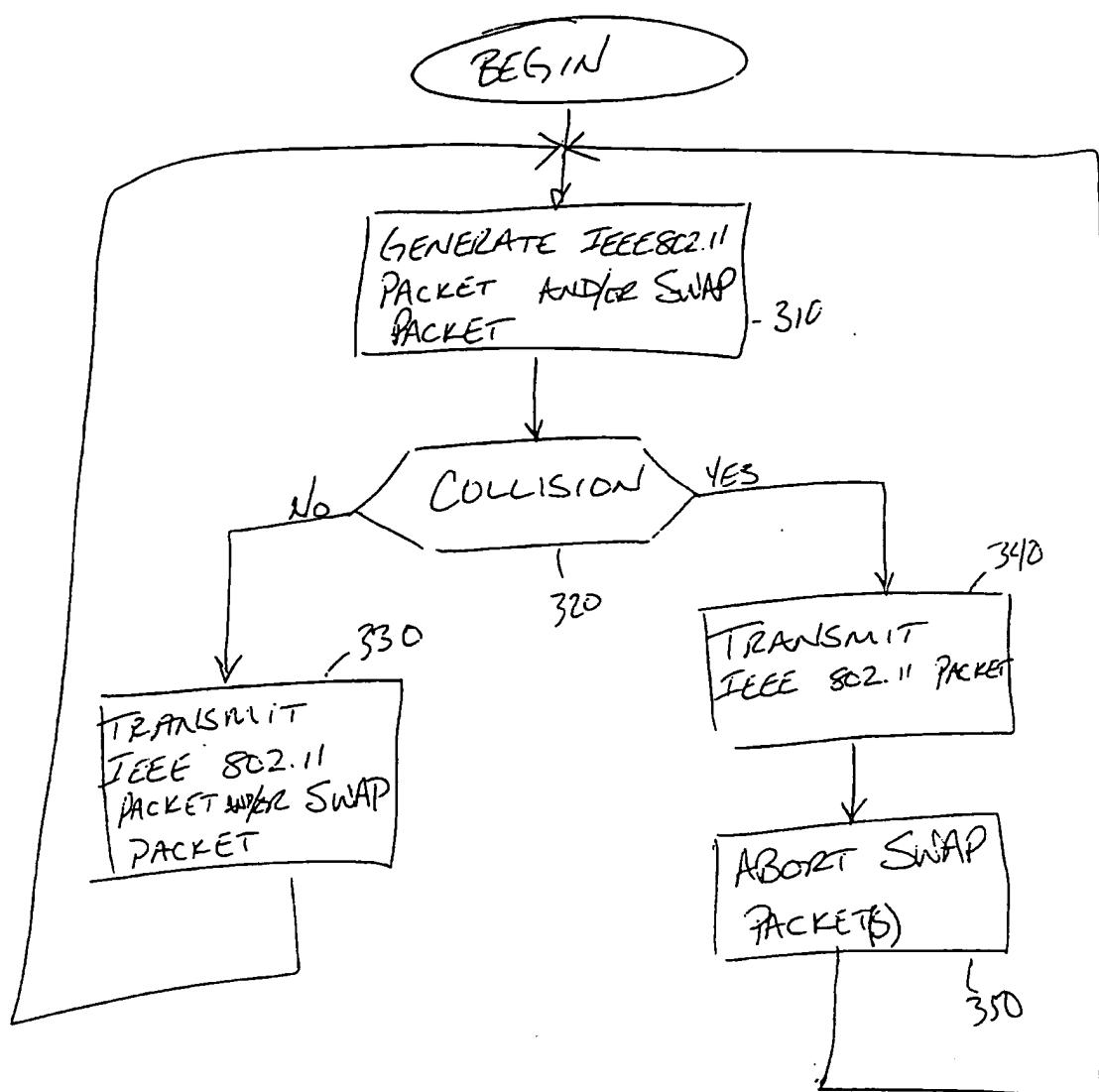


Fig. 3

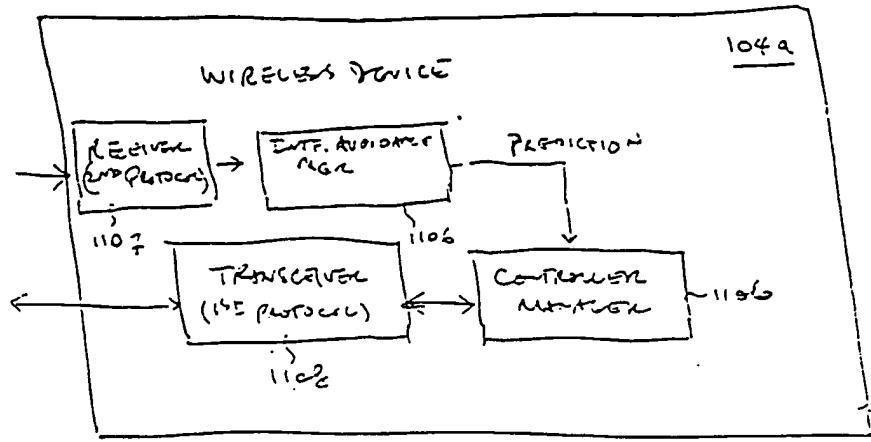


FIG. 4a

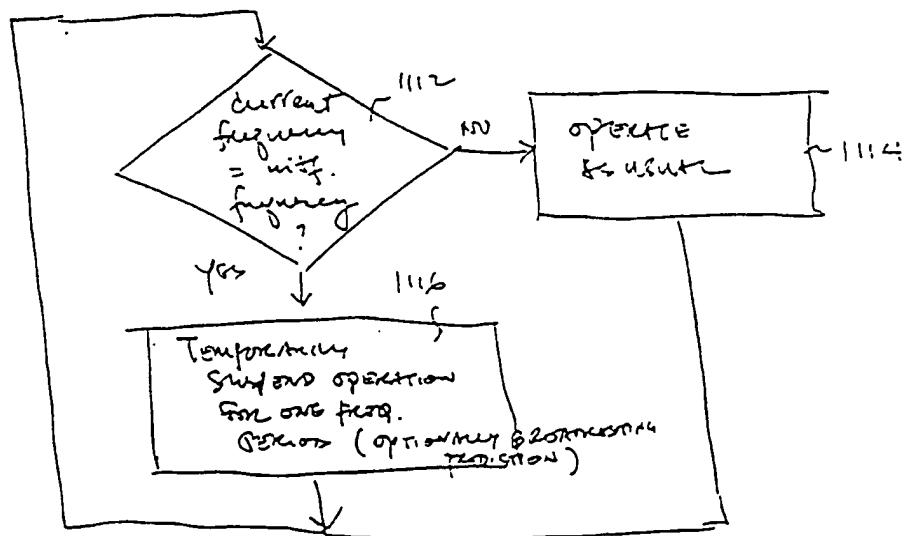


FIG. 4b

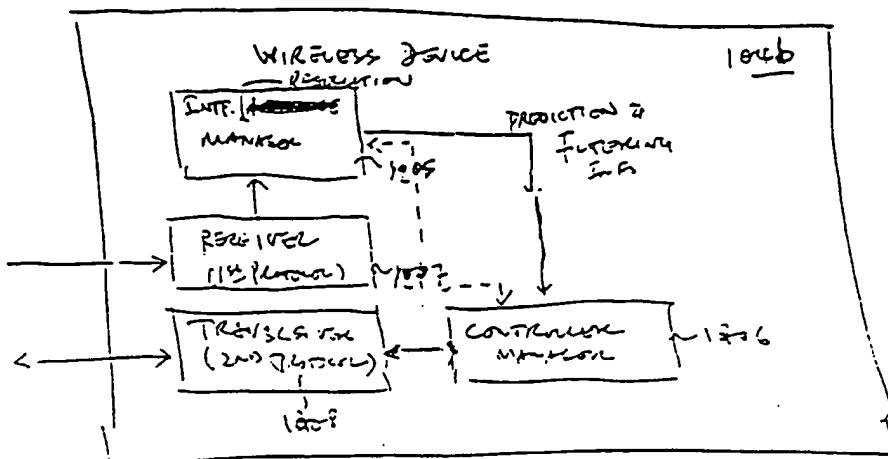


FIG. 5a

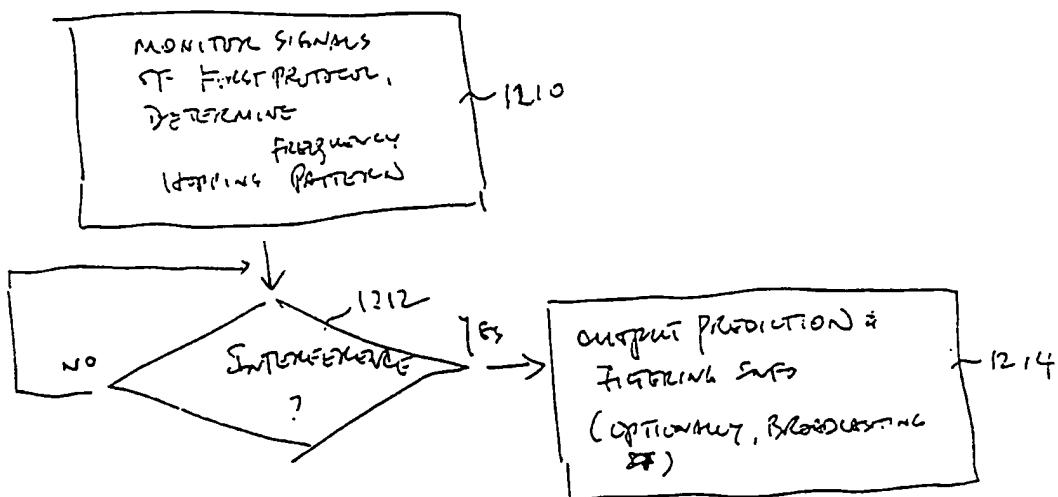


FIG. 5b

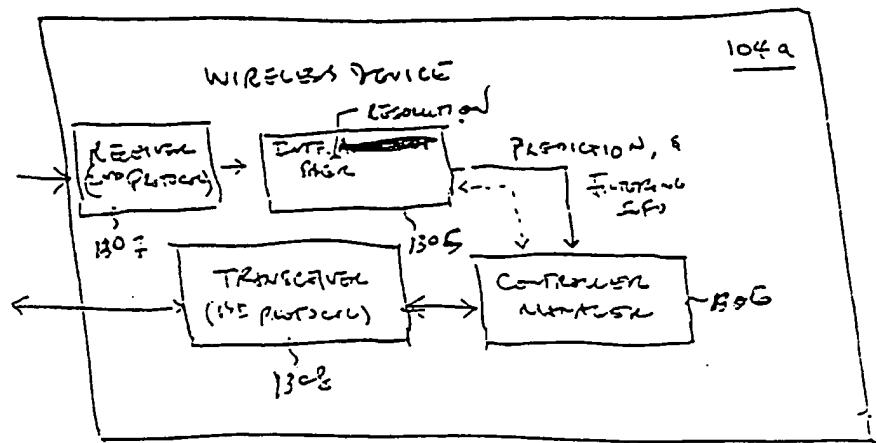


FIG. 6a

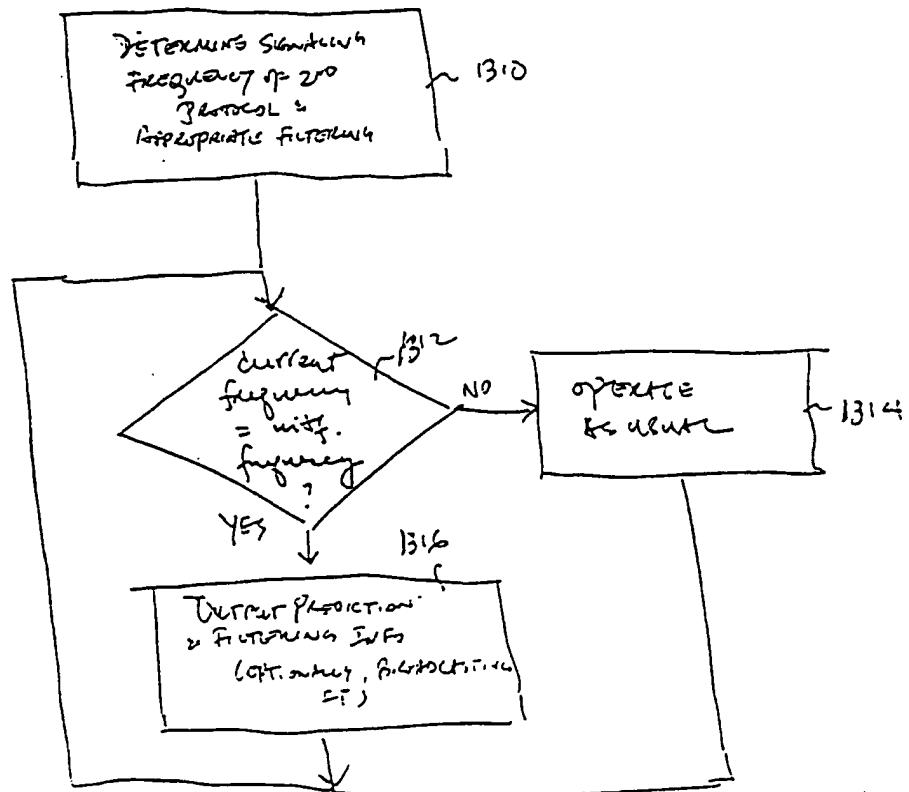


FIG. 6b

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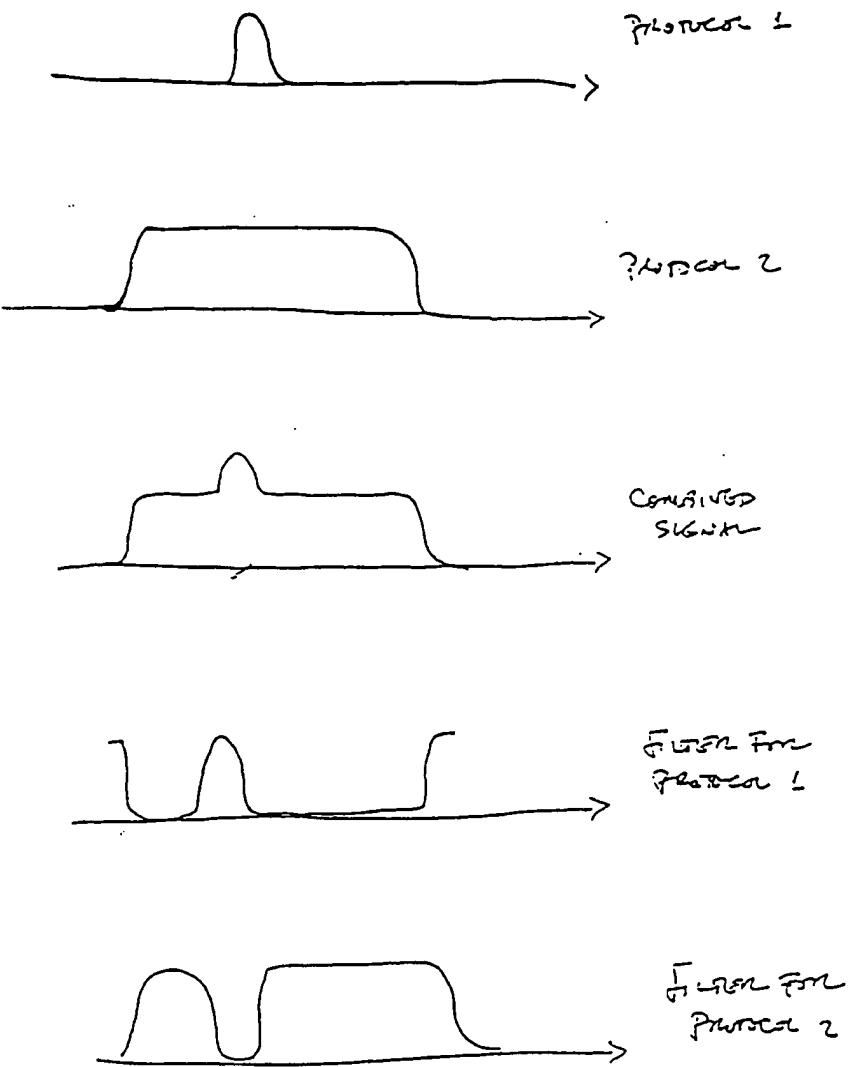


FIG 7

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 00/26857

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H04L12/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04Q H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|---|----------------------------------|
| X | <p>WO 99 29126 A (JOERESSEN OLAF J ;NOKIA MOBILE PHONES LTD (FI)) 10 June 1999 (1999-06-10) page 1, line 5 -page 3, line 4 page 5, line 12 - line 14 page 7, line 1 - line 4 page 11, line 20 -page 13, line 24 figures 4,5,7,8 ----</p> <p style="text-align: right;">-/--</p> | 1,4,5,7, 9,12-14, 16,19-21 |

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the international search

30 January 2001

Date of mailing of the international search report

06/02/2001

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel: (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Barel, C

INTERNATIONAL SEARCH REPORTInternational Application No
PCT/US 00/26857**C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|----------|---|-----------------------|
| A | NEGUS K J ET AL: "HOME RF TM AND SWAP: WIRELESS NETWORKING FOR THE CONNECTED HOME" MOBILE COMPUTING AND COMMUNICATIONS REVIEW, US, ACM, NEW YORK, NY, vol. 2, no. 4, 1 October 1998 (1998-10-01), pages 28-36, XP000786057 page 29, right-hand column, last paragraph - page 30, left-hand column, paragraph 2 page 33, left-hand column, paragraph 1-2 ----- | 3,11,18 |

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Information on patent family members

International Application No

PCT/US 00/26857

| Patent document cited in search report | Publication date | Patent family member(s) | | Publication date |
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